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ABSTRACT

This research investigates the ways people learn from multimedia and how navigational patterns can be incorporated into the design structure. The paper begins with a discussion of present navigational research and then presents the results from the initial empirical work, including a pilot study of primary and secondary children using multimedia and a main study that looks at the ways adults use multimedia. A new classification for navigational patterns, developed from information in the initial study, is outlined. The following nine types of navigational patterns are described and compared with the work of other researchers: linear; linear extra; circular; star; star extra; hierarchical; hierarchical-extra; complex-chaotic; and complex-planned. The discussion then moves to learning strategy research. The following learning strategies developed from the research are linked to the navigational patterns and the work of other researchers: orientation; ordered/structured-linear, ordered/structured-circular; systematic/hierarchical; complex-random; and complex-planned. It is concluded that students have their own individual preferences in how they navigate through software and how they approach learning from it; benefits of multimedia include allowing a personalized pattern of work as well as the ability to progress at an individualized pace. (Contains 17 references.) (AEF)

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Navigational Patterns in Interactive Multimedia and Their Effect on Learning

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Abstract
Research on navigational patterns in interactive multimedia outlines previous research and then proposes a new set of navigational patterns from the empirical work, and comparing these to the earlier patterns. Empirical work tested these and assessed differences between novices and experts, and children and adults. Differences in navigation can be explained by factors such as :- how the users have been taught to use software, their usual learning or teaching methods, their exposure to computers and multimedia, their age range and the specific task. Methods of defining and encouraging learning strategies in multimedia are investigated and a usable classification developed. The benefits of multimedia for individuals are outlined e.g. personalised work patterns. The conclusions, state that most users have preferred methods of navigating and learning strategies and these methods, the benefits for the individual learner and the link between navigational patterns, experience and learning strategies are important.

Introduction

The construction of multimedia packages to date has usually been developed along conventional software design. However the unique learning environment which can be created when using multimedia means that innovative methods of constructing packages must be encouraged in order that the facilities and qualities of multimedia can be exploited to give the best learning environments. My research investigates the ways people learn from multimedia, and how we can incorporate these into the design structure. This paper commences with present navigational research, it then investigates the results from the initial empirical work. A new classification for navigational patterns is then outlined and these patterns are then tested by further empirical studies, where the users actual navigational patterns will be analysed in terms of my classifications and these are then compared to those of other researchers. Finally work on learning in multimedia is detailed and some methods of defining and encouraging learning within multimedia are developed, by proposing a series of learning strategies.

Research on navigational patterns

Horney's work (1993) is important here as he investigates users using hypertext and discovers five navigational patterns, namely Linear Traversal, Side Trip, Extended Star and Chaotic. His patterns can be described as :- Linear Traversal where the user visits each nodes in order, moving in a linear pattern; Side Trip which is mainly linear but with visits to other nodes not on their main path and is a more than the first; Star pattern, which uses a central or root and returns to this; Extended star which includes nodes the user wants to revisit, such as out and back cycles and Chaotic where the user has different traversal methods and randomly moves through the document. Horney does not fully explain his star pattern but this appears to differ from his linear one if the user moves to a different level in the package, this is the criteria I have used to determine the difference between linear and star and it seems that Horney had a similar distinction. Horney's view of the chaotic pattern was that these users were not lost, but that their navigational routes were too complex for a more regular pattern to be discerned and therefore the Chaotic pattern could be a mixture of other patterns.

Parunak (1989), also looks at various strategies people use and produces a series of topologies to relate to them. He identifies five common strategies:- Identifier, Path, Direction, Distance, and Address, where the Identifier allows the user to distinguish the target; path follows a definite linear route (and could be a basic component of other more complicated strategies); and direction, such as north. However direction is more of a working method, rather than a distinct pattern. The next strategy, distance limits the search to a distinct circle around the current location and address gives it a specific location. Parunak then briefly develops six topological structures to support these strategies which are - Linear, Hierarchy, Hypercube/ Hypertorus, Directed Acyclic Graph and Arbitrary, which I find much closer to my navigational strategies than are his navigational strategies, which look at methods of navigating rather than at patterns and so I have used his typologies to relate to my navigational patterns. His first linear topology, is straightforward and presents a one-way linear route but it can also form a ring, (as in my circular definition), but if it uses different levels this would be classified as my star pattern, not linear. Parunak's second topology is Hierarchy. The next topology Hypercube/Hypertorus is difficult to relate to multimedia as there are few software packages that would conform to this structure. The next topology is one called DAG - Directed Acylic Graph. My view of this strategy is that it is too similar to the hierarchical one to be categorised separately. The final topology is arbitrary, which consists of any connected graph, this could be a huge category and probably needs subdividing. In Parunak's categories the linear, ring, hierarchical and arbitrary topologies can be broadly compared to my classifications. Having looked at the two main contenders for

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navigational patterns I now want to investigate the work of others whose research has influenced my work. Trumbull, Gay and Mazur (1992) experimented with a system which had three different built in navigational and guidance tools :- index, guide and browse. The Index allows the user to search through a textual description of the topics, Browse enables users to use screen commands to move through the package and the Guide provides an online advisor. The three navigation tools were designed to allow users to decide on their own strategies for obtaining information. The results from the survey identified four distinct groups of users, all of whom were classified by using the individual navigational tools for varying amounts of time - Browsers (89% of time), Indexers (65%), Guiders (26%) and Mixers who used all the tools. Hammond and Allinson (1989) also support Trumbull et al's conclusions that as the students were using different strategies, designers should develop a variety of interfaces that allow for different search strategies. Trumbull et al's work is particularly relevant to my research as it looks at the use of particular tools to navigate through multimedia and these tools can be compared to the different ways of approaching an encyclopaedia. Beasley and Vila's (1992) work looked at two main areas, namely the relationship between navigational patterns in multimedia and academic ability, and secondly whether these patterns related to gender. They identified patterns of access in terms of linearity or non-linearity and examined the relationship between these patterns of access and learner aptitude. They stated that females took a less exploratory approach than males, however this appears to be only true for the lower ability female group, while males of higher ability use non linear methods. Mischanuk and Schwier's (1992) work which discusses the use of audit trails in interactive hypermedia is potentially very useful. Their audit trails involve recording each screen that the user visits and factors such as :- the number of repeat visits, how long they spent on certain sections and the exact paths they took, are useful. They suggest four distinct types of audit trails, but state that in reality these are often combined within programs. Their four types are linear, classic feedback loop branching, learner controlled parallel path branching and multimedia/ hypermedia. The first linear is the basic path recognised by several researchers. The second branching structure allows some paths to reconverge, this path resembles my star pattern. Their third structure - branching paths run parallel to one another and converge and the learner then continues on the instructional sequence, rather like my hierarchical one. This final path has the most complex structure and is much more variable than the others. They then give ways of utilising these audit trails :- formative evaluation in instructional design, basic research in instructional design, usage audits and counselling and advising. Hence Mischanchuk and Schwier's results are broadly comparable to mine, except for the fact that they have only found four main types of trails and I believe it is possible to differentiate these patterns into more finite types.

Canter, Rivers and Storrs (1985) looked at user navigation through interactive databases and discovered a set of indices to characterise users search sequences which could give more precise definition of strategies such as browsing, looking at crucial factors such as the task the user is performing and their preferred strategies. They developed six indices to characterise users navigational behaviour:- pathiness, ringiness, loopiness, spikiness, NV/NT and NV/NS. Pathiness describes a route through the data which does not cross any node twice, a typical linear path in my classification. Ringiness, a route through the data which returns to the starting point, is simple and closed, and is like my circular route. Loopiness, is a route in a ring shape which contains no other rings, the main difference from the ring being that the latter usually emanates from a specific base node and is usually the only route from that node. Spikeness is a route which retraces the path taken on the outward journey in exactly the same way and is most like my Star extra pattern. NV/NT is the ratio of number of nodes visited, to the total number of nodes available in the system and gives the proportion used by each individual. Finally Zhao (1992) found that the same type of navigational strategy was adopted by nearly all of his subjects. Zhao describes how he found three types of browsing - hierarchical, depth first search-like and chaotic. He finds that there are a variety of factors which affect the navigational strategy applied by a user such as the hypertext topology, interface design, navigation tools, learning objectives and learner individual differences.

Empirical Work

The empirical work for this study has involved a pilot study of primary and secondary children using multimedia and a main study which looks at the ways adults use multimedia, how they commence using a package, how they navigate through particular routes and how they approach projects. The pilot study used a range of commercially available software, such as The Way Things Work, Grolier's Encyclopaedia and Medieval Realms, among others. The first task involved a short browsing or orientation session, where the pairs of children were allowed relatively free access to the software, followed by a more restrictive set subject that they researched and where their exact routes were recorded and a final task asking them to assess how the material they had been using was structured and if possible to describe or draw the layout. My initial empirical research showed that younger students have very distinct preferences for certain types of multimedia packages, but also that older students were much more task orientated and that they found browsing more difficult and time consuming than the younger ones. These results are also comparable to some of those from Misanchuk and Schwier. Information from the pilot study which is useful to the main study includes the navigational patterns used, the type and nature

of the tasks given to the users, the amount of work possible within the allowed time and problems with recording. This has allowed an analysis of the navigational patterns used, ranging from a simple linear structure through to complex patterns. Furthermore for most users there seems to be either one preferred pattern or a limited range of patterns that they habitually use. However most of these users were new to multimedia and their selection of particular patterns may alter with longer use of such packages, although even more experienced users of multimedia did have preferred patterns of use. In the main study adult students were asked to perform various tasks with a selected multimedia package to assess their navigational patterns and their learning. Both pre and post questionnaires were performed. The pretest questionnaire covers aspects of the students previous computer and multimedia use and their interests. The post test questionnaire asks for some factual responses to specific questions relating to the knowledge they have learnt in the test, and then continues in the form of an interview, where their opinions on the software and their method of navigation are investigated. The following hypotheses will be investigated :- that each individual has preferred methods of using multimedia; that certain navigational patterns are more beneficial to the learning process than others; that navigation patterns can encourage deep learning; that beneficial navigation patterns can be learnt and reused; that experience can improve learning from multimedia; and that controlled use of multimedia can improve learning. Encarta was chosen as the encyclopaedia which allowed the most flexibility and greatest range of navigational patterns, as well having a resource pack which detailed ways of using the package for research and gave templates and instructions to teachers on how to use the package and examples of its use. These are :- an exploratory Task 1, an investigative approach which forms the main sequence of set tasks (Task 2), and a final open task (Task 3). The first task is a browsing task (15 mins) which should allow the individuals personal preferences on navigational patterns and their interests to be determined. The second task is to search for information on a topic in four different conditions. These four navigational routes are linear, circular, hierarchical and complex. The amount of user choice will increase through each of the four patterns. This second task is used to assess navigational patterns, whether or not users keep to the prescribed or flexible routes, how often and in what manner they diverge from these paths, and the learning that is achieved during this time. The third task involves users selecting a topic and researching it within the package for 25 mins.

Results of the main study

From the empirical work in this research it appears that most users have a preferred set of navigation methods. The most popular combination is linear and hierarchical patterns, which appears to be the case across the expert to novice groups, with some users being very linear. These users seem to be very methodical, but as the students who strongly prefer the linear approach are mostly novices this may represent the way they have been taught or the way they usually approach learning, i.e. in a sequential manner, although this may not be the most successful approach with multimedia. Intermediate users proved to be very variable in their preferences, although there were only a few of these, so this may represent the range within the sample rather than the way this group of users would normally perform while the expert users tended to be very complex and this suggests they may have been using certain strategies for certain tasks. The expert users use many other types of routes, some in part, but generally in a more mixed way, showing abilities in switching to different methods or changing their strategy. Most of simpler routes are favoured by novices, the intermediates are slightly more adventurous but it is the experts who on the whole are much more likely to branch out, try different strategies and to follow different navigational patterns for each task. There seems to be a fundamental difference in how inexperienced people choose to navigate, or how they commence using the package and how the experts do this, as their navigation is much less purposely followed, it appears to be much more intuitive, especially if they reach a dead end, when they are much quicker at re-assessing where to go next than the other two groups.

Fig. 1 Main navigation Routes Used (20 Students in all)
Very linear/ little hierarchical - 2 Users (Novices)
Linear and Circular - 1 User (Intermediate)
Linear and Star, some hierarchical - 1 User (Novices); 1 User (Inter)
Linear and Hierarchical - 4 Users (Novices); 1 User (Inter); 4 Users (Experts)
Complex and Hierarchical - 1 User (Inter)
Complex users - 5 Users (Experts)

The linear route is the most common, although not the most frequently used route. Most users need to have some sequential movement through the resource, although this is more noticeable in the novices. There are fewer example of the use of the linear extra route and perhaps this is a variant of the main type rather than a specific route on its own. There are relatively few examples of the circular route in this group of users, although there may be some examples of users using it for small amounts of time. It was much more prevalent in the pilot study as younger users seem to use this, as well as the star pattern, to check that they have covered everything and as an orienteering device, have a quick look around, and come back to the beginning before going on. The star and

star extra are also relatively little used in the adult groups. Most users seem to use the hierarchical or hierarchical extra pattern at some stage during their search, with the possible exception of some of the very linear preference novices. Also some of the children in the pilot study rarely, if ever, used a hierarchical pattern. For most users the use of the hierarchical pattern comes after the initial use of the linear or star pattern, i.e. in the middle of the search. The complex chaotic users are all confined to the expert group and only occur quite rarely. The complex planned type of navigational pattern is the more common of the two types of navigational patterns in this category and is again only used by the experts. The experts were much more competent users and were much faster, covering a lot of ground and making quick decisions. There are several links between the pilot and the main study. Firstly the younger students in the pilot study also had distinct preferences in their choice of navigation routes. Most of the younger students preferred either a linear or a hierarchical route while some of the students also used the star and circular routes. In the main study the linear and hierarchical routes were again most common, although most users used some linear followed by a hierarchical pattern for different stages of the research, rather than the younger students habit of selecting either a linear or a hierarchical route. Few of the pilot study students used several patterns and none were complex users. In the main study there were some users of multiple patterns which became the complex users. The star and circular pattern also seem to be more common with the pilot study students than the main study students.

Development of my own series of navigational patterns

I have developed a series of navigational patterns from the information gained in the initial pilot study. For this research a broad genre of types is sufficient to adequately describe the patterns and to distinguish them from one another, future research may enable further more finite classification. The detailed descriptions of each type follow and are then compared to the types found by other researchers (Fig 2). My list has been created by comparing individual or groups use of multimedia All the users patterns observed could be put into these categories, although obviously there are more in some categories and the latter two categories of complex, chaotic and planned may need further refining as it is possible that these may provide a final classification for all the complex or unusual patterns as well as the very complicated ones.

Description of Navigational Patterns

The following types of navigational pattern have been discerned, with a short description of each :-

1 Linear - Following path on same level, using index, time line, or word search features, usually one way.

2 Linear extra - Mostly as linear pattern but some paths/routes leave this, then return to path.

3 Circular - Initially and in some incomplete forms recognised as linear, when complete can be one way or two way becomes arc or circle when nearer completion, or is dependent on the design of the software.

4 Star - Moving along in linear fashion but changing level, going into all or some second level areas from first level and returning, can be one way or two way, breadth first qualities, going into complete star pattern, selection all through package especially in those with a circular or thematic structure e.g. looked at all themes and moved into second level.

5 Star extra - User goes into 2nd/3rd level of package, i.e.additional level, beyond usual star boundaries.

6 Hierarchical - User moves down hierarchy and then may return to go down one or more other branches of tree structure, usually one way down structure and across or return to next branch of tree structure, depth first qualities, can be two-way, although not usually totally returning to original starting point.

7 Hierarchical - Extra, can go along multiple hierarchies, different subject/ types but all in the same way, can return to same tree structure or may continue onto linked tree structure, i.e. several branches of same tree.

8 Complex - Chaotic, Random use of navigation, may be mixture of some of the above types.

9 Complex - Planned, Sequence of moves following established paths, can usually see which patterns are being used, a mixture of different types but forms ordered route through resource. The types can be mixed within the route, i.e. some recognition of each type but too confused or short to classify as each individual pattern.

Fig. 2 Comparative Navigation patterns

Horney	Zhao	Parunak	Canter	Fenley
Linear	-	Linear	Path (Pathiness) any route not crossing node twice	Linear
Traversal				
Side Trip	-		Loop (Loopiness) ring which contains no other rings	Linear - Extra
Star	-	-		Star
Extended star	-		Spike (Spikiness) retraces path back	Star - Extra
	-	Ring	Ring (Ringiness)	Circular

			Returns to start node, may include other rings	
	Hierarchical	Hierarchical	-	Hierarchical
-	Depth First Search like	DAG	-	Hierarchical - Extra
Chaotic	Chaotic	Arbitrary	-	Complex - Chaotic
		Hypercube/ Hypertorus		Complex - Planned

Comparison of my patterns with other researchers

There are some links between my work and that of the researchers above, especially Horney. There are links with most of his search patterns, although he probably does not extend his classifications far enough. Comparing Parunak's work I can find relatively few links with his strategies, although hi topologies are very relevant and can be linked into my classifications quite neatly. In Trumbull et al's work their Index strategy is like my Star pattern, the Browser suggests the Linear pattern or Horney's Linear Traversal and their guide perhaps - Side Trips or my Linear extra. In Beasley and Vila's work their linear strategy links perhaps to Horney's Linear Traversals or a generalised linear pattern and is similar to my basic linear route, however their non linear pattern is perhaps most similar to Horney's Side Trips, which in Horney's classification system is not really hierarchical, and perhaps slightly to my hierarchical pattern. Hence most of the research has some links to my patterns, but on the whole is less comprehensive and suggests that there are more routes or ways of looking at navigation and most of the researchers have concentrated on quite a narrow range, when compared to my more global approach.

Learning strategy research

The next area of research to be discussed is that of learning cycles which I also investigated, looking at those proposed by Kolb, Driver and Laurillard. The stages in Kolb's (1984) experiential cycle include Experience, Description, Analysis, Generalisation, and Action Plans. Driver's model (1988) covers more of the necessary stages with orientation, elicitation of ideas, restructuring of ideas, clarification and exchange, exposure to conflict situations, construction of new ideas, evaluation, application of ideas, review change in ideas, comparison with previous ideas; but it is a rather linear sequence, whereas Laurillard's has the cyclic process but also includes more reiteration as well as input from the teacher, which she considers to be crucial. Laurillard's cycle (1993), which is perhaps the most applicable to multimedia design, includes stages for both the teacher and the student:- the teachers conception, then the student conception, discussion then the teachers redescription and the students redescription, then reflection and adaption, before more discussion or interaction, then the third part task goal, action, feedback, modified action more interaction follows and the fourth part of the cycle which involves another period of adaption and reflection. Research on the way people learn from multimedia has involved looking at the work of people such as Yildiz and Atkins, Barker and King, and Self.

Yildiz and Atkins (1993) criteria for evaluating multimedia has also been useful to my research as they suggested a whole list of reasonable factors in evaluation which I would support, notably that evaluation should concentrate on courseware characteristics, the user and the learning task rather than the platform; that the software should be exploited to the maximum; that implicit beliefs on student learning methods should inform the design; that the learning context is important and that the evaluation of outcomes, conceptual learning and higher order conceptual skills are essential. Barker and King (1993) suggest the use of self-anchoring where their points of view are anchored graphically or numerically. Their research also highlighted engagement as being highly rated in good multimedia as is tailorability and interactivity, all features which I would agree with. John Self (1995) has been using student modelling with multimedia and in particular stated that 'developers of multimedia learning systems are realising that presentation needs to be adapted for individual learners'. Finally my learning strategies are compared with those of Trumbull, Gay and Mazur; Midoro and Pedemonte; Canter et al; and Conklin. Conklin (1987) states that the browsing of a database can be done in three distinctive ways; by following links, and opening windows successively; by searching all or part of the network and thirdly by navigating around the hyperdocument, using a browser that displays the network graphically. Trumbull, Gay, Mazur (1992) grouped their users according to which of three main navigational tools they use predominantly the Browser, Index, Guide, or a Mixed group. Canter, Rivers and Storrs (1985) work used the type of paths found, e.g. pathiness, but as they also discovered five search strategies to do with ways of learning, their work is also included here. These five strategies are defined as Scanning (mixture of deep spikes and short loops as users seek to cover a large area but without great depth), Browsing (many long loops and a few large rings, users go where data leads until interest is caught), Searching (ever increasing spikes with a few loops for users motivated to find a particular target), Exploring (many different paths, suggesting users are seeking the extent and nature of the field), and Wandering (many rings as the user ambles along).

Description of the learning strategies

From an investigation of this work from other researchers and observations a series of learning strategies have been developed, which can be used singly or in conjunction with the navigational patterns above, these are compared to the other researchers in Fig 3. The use of terms such as browsing is open to abuse as different researchers have applied the term for a whole range of diverse activities and it is more helpful to be more specific as to what each of the activities refers to. Many of these could be attributed to more generalised browsing, and so I have been much more specific in both the naming of the terms and in allocating their use to certain observations. The following list outlines the learning strategies found:-

Orientation, Ordered/ Structured -Linear -Circular, Systematic/Hierarchical, Complex - Random and Complex - Planned. The table below links these with the strategies from other researchers :-

Fig 3 Comparative Learning strategies

Trumbull et al	Conklin	Midoro/Pedem.	Canter	Fenley
Browse	Following links -opening windows	-	Scanning large area -no depth	Orientation delimiting/ quick
Index	Searching the network for string	Topics/Index	Browsing- path to goal achieved	Ordered/ Structured - -Circular
Linear				
Guide	Navigating using Maps network graphically		Searching - find explicit goal	Systematic/ Hierarchical
Mixed	-	Dictionary Anthology - author	Wandering- purposeless, no structure	Complex - Random
-	-	-	Exploring /finding extent of info given	Complex - Planned

There is an element of experience in the use of all search strategies, i.e. does repeated use refine the methods of use and the effectiveness of a particular strategy, or are experienced users likely to develop complex ways of investigating multimedia resources. Frau, Midoro and Pedemonte's (1992) work is very relevant here and can be compared to this study as they concentrate on the modes of interaction and the strategies students use to investigate the software, the problems they encounter using the system and its learning effectiveness. They suggest supervisor functions should be:- the selection of topics to match educational objectives and learner status, choosing the next best topic and the best strategy for that topic, and selecting the best unit of learning (ULM) to both implement the strategy and perform the given educational function. Questions that Frau et al are asked of the students, such as how long do they spend on each activity, what order they proceed in, problems etc, are similar to the questions asked by Laurillard in her student assessment work (1993). Their second aim is to analyse how effective the learning is, an aim which is very close to my own study. They decided on a qualitative approach and assessed different strategies of browsing and the learning that resulted. Interestingly they impose two conditions; a self service mode with no explicit task (similar to my initial browsing task) and task guided navigation, which can be compared to my task based exercises. Frau et al also find that 20% of the time is spent working out how the system worked, understanding and accessing functions, by deductive (looking at system, seeing if appropriate) and inductive methods (using material and then looking for system information). Their results are based on users interviews and the changes in their concept maps and suggest that some students have acquired new knowledge, many others acquiring a lexicon of terms and fewer students understanding the underlying concepts. Looking at the learning strategies, although both groups tended to use some form of linear strategy at some stage in the session the younger students more frequently used the rapid orientation style and less of the ordered strategy, while only some of the pilot group used a hierarchical pattern this was much more common in usage by the main study users. There are also links between the navigational patterns that students use and the learning strategies they use. The experts again have the majority of the links as they tend to use more patterns and strategies generally and are usually able to determine which of these are most suitable for a specific task and use it. The novices are more restricted and will often remain with the one they know rather than try something new. The students that predominately use linear patterns in the navigation are also the most prone to use these, especially the order structure in the way they learn, although there is a small overlap with the hierarchical methods. The experts tend to be more willing to use hierarchical rather than linear learning strategies and link more of the information to outside sources via hot text. There again seems to be some individual preference for particular learning strategies, although this is not as strong a preferences (or set of preferences) as in the navigational patterns. However there is less of a link between the navigational patterns and the learning strategies used in the pilot study than in the main study.

Conclusions

The main element of this research has been exploring the navigational patterns that users employ. External factors may have an effect, such as:- how the users have been taught software, their usual learning or teaching methods, their exposure to computer and multimedia, their age range and the task they have been given. The findings of the research suggest that each student has their own individual preferences in how they navigate through software and how they approach learning from it. If we are to encourage students to construct their own learning environments in the constructivist sense then we must encourage them to develop their skills on directing their own learning and in becoming aware of methods of increasing or improving learning, in other words allow them to develop themselves but give them the skills and abilities to be able to do this. If motivation is increased and students can select their own options this deep approach should allow the potential of each individual to be reached. Multimedia can enhance this process by allowing students to develop themselves and providing individual help angled for that particular student and given to them, both in terms of instruction and content as well as help, in the way they prefer and in the manner in which they are likely to gain the most from it. The main empirical work has shown the benefits of multimedia for individuals such as allowing a personalised pattern of work and being able to progress at their own pace. The results of the main empirical work help to support some of these factors and the hypotheses and create some more definable links between navigational patterns and learning in multimedia.

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